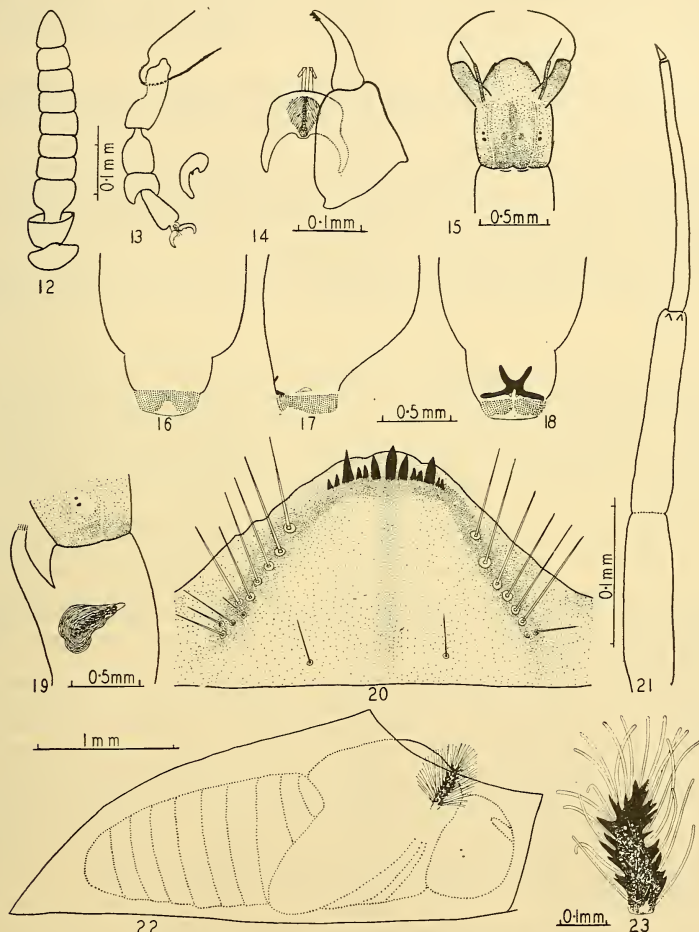AUSTROSIMULIUM MAGNUM, n. sp.

Types. Holotype ♀, allotype ♂, morphotype larva and pupa, from Little Crystal Ck., 45 m. N. of Townsville, North Queensland, 1,100 ft., November-December, in Division of Entomology, C.S.I.R.O., Canberra, A.C.T.

Text-figs. 12-23.—*Austrosimulium magnum*, n. sp.

12, antenna of female; 13, hind tarsus of female; 14, hypopygium of male; 15, head of larva; 16-18, posterior end of larva, ventral, lateral and dorsal views; 19, gill-spot of larva; 20, submentum; 21, antenna; 22, cocoon and pupa; 23, respiratory horn of pupa.

Distinctive Features.

A large species, 3–3·5 mm. long. ♀: Distinguished from all other known Australian members of the genus by having a pattern of white hairs (not white tomentum) on the abdominal tergites. ♂: Also distinguished by having white abdominal hairs, which are

less conspicuous and more scattered than in the female. *Cocoon*: Resembles *A. bancrofti* in texture and in possessing a well-marked collar. *Pupa*: Respiratory horn resembles that of several species of the *mirabile* group; however the combination of a black, spiny pupal horn and a *bancrofti*-like collar on the cocoon is quite distinctive. *A. torrentium* also has a spiny horn and collared cocoon, but its cocoon is peculiarly broad and flat, with the thorax of the pupa fitting firmly into the opening and held in position by modified hairs. *Larva*: Distinguished by its large size, *Cnephia*-like shape, and extremely wide posterior circlet.

The affinities of this species are difficult to assess. It has distinctly *Cnephia*-like features in the vestiture of the abdomen of the adult, the shape of the larva, the form of its posterior sclerite, and its very wide posterior circlet. In other respects, however, it is a true *Austrosimulium*. Within the genus, it resembles the *mirabile* group in the toothed claws of the female (though the tooth is in a different position) and in the spiny respiratory horn of the pupa. In other characters (frons and antennae of female, hypopygium of male, cocoon, pupal chaetotaxy, absence of ventral papillae on larva) it conforms to the *bancrofti* group, the definition of which, however, will need to be modified in the following terms in order to include it:

Claws of female simple or with sub-basal tooth; abdomen with pattern of pale tomentum or hairs. Larva without chitinous ring anterior to circlet; ventral papillae absent.

Female.

Head. Frons wide, tapering towards antennae, about one-fourth head width at narrow part, with greyish tomentum and creamy-white hairs. Face grey, with white hairs. Antennae with first three segments creamy to yellowish, the third darkening apically; remainder dark brown, with short dark and scattered silvery hairs; the second and third segments are the largest, but are not unusually enlarged (Text-fig. 12). Proboscis and palpi dark brown, with dark hairs, and with some silvery ones anteriorly on proboscis.

Thorax. Scutum and scutellum dark brown, densely covered with small golden to creamy-golden hairs. Postscutellum rather shining, bare, dark brown, with brilliant silvery reflections. Pleurae brown, with silvery reflections, particularly in the pre-alar area. *Legs* dark brown, with dark brown and creamy golden hairs; hind femora and tibiae robust. Calcipala well developed; claws with a small tooth lying between basal swelling and shaft (Text-fig. 13). *Wings* clear, with brown veins; halteres with stem brown, knob creamy.

Abdomen. First segment brown, with white to creamy-yellow fringe; second to fourth and part of fifth tergites velvety black; remainder dark grey, bare but not shining; all with conspicuous white hairs, which are particularly concentrated in certain areas to form a fairly well defined pattern. In most specimens, there is an apical white band on the second tergite, a median white vitta, sometimes interrupted, from the apex of the third to the apex of the fifth, and white apical bands on the same tergites; the sixth and subsequent tergites are more diffusely white. The pattern varies in extent and arrangement, but the white hairs are always conspicuous, and form a unique character in Australian members of the genus. Venter dark brown, the apices of the sternites paler, with silvery hairs which tend to be arranged in bands.

Male.

Head. Upper facets of eyes moderately enlarged, up to $0 \cdot 035$ mm. Antennae more slender than in female, and basal segments darker. Face grey, with silvery reflections; proboscis and palpi blackish-brown.

Thorax. Scutum velvety black, densely covered with short, rich golden hairs, which are longer and more conspicuous in front of and on the scutellum. Pleurae and legs darker than in female.

Abdomen. First segment black, with dark brown fringe laterally, and some shorter, paler hairs medially; remaining tergites velvety black, with scattered white hairs, which do not form the definite pattern seen in the female, but are relatively conspicuous

on either side of the median line at the base of the second tergite and more laterally on subsequent tergites. The extent of the white hairs is variable, but the zone on the second tergite seems always to be present. Hypopygium (Text-fig. 14) without striking features; style with two or three terminal spines. The shape of the anterior part of the phallosome, the arrangement of its ventral setulae, and the irregular posterior part of the phallosome, with denticles not detectable, suggest affinities with the *bancrofti* rather than the *furiosum* group.

Cocoon.

Length 3·5 mm. Finely woven, with neat rolled edge; there is a well developed collar, but no trace of central dorsal projection (Text-fig. 22).

Pupa.

Length 3·2 mm. The integument of the head and thorax is ornamented with minute flat tubercles. On the head, there is a broad median bare streak bearing very few tubercles, but they are densely massed on each side. On the thorax, there is a row of tubercles on each side of the median suture, then a relatively bare streak on each side, gradually merging into the thickly covered lateral areas. The tubercles are grouped in rosettes of 4–6. There are two pairs of cephalic hairs with fairly stiff bases and fine tapering ends. The thoracic hairs are similar, except for the most posterior of the dorsocentrals, which are modified to form strong hooks.

The abdominal chaetotaxy resembles that of the *bancrofti* and *furiosum* groups, as distinct from the *mirabile* group. The first and second tergites bear five pairs of fairly stiff hairs; the third and fourth have four pairs of strong hooks, directed forwards and situated near the mid line; the fifth to seventh each has four pairs of similar hooks, which are more widely spaced than those on the third and fourth; the eighth has six pairs of minute, curly, anchoring hairs, and the ninth a pair of tiny terminal hooklets. The ventral surface appears bare.

The respiratory organ consists of a short, black, spiny stem, from all parts of which there arise fairly short, fine filaments (Text-fig. 23).

Larva.

Length 7–8 mm. Greyish-brown, with pale area postero-ventrally. Head heavily chitinized. Pattern on dorsum a median dark longitudinal streak, merging into a dark transverse band along the posterior border. There are two dark patches, one on each side of the mid line. Anteriorly, the fronto-clypeus is raised into a dark ridge on each side running antero-medially from near the base of the antennae (Text-fig. 15). Similar ridges have been seen in some *Cnephia* larvae, particularly in *C. strenua* (Text-fig. 21) are dark brown, and project well beyond the basal piece of the fan. The submentum (Text-fig. 20)) contains 13 teeth, of which the central and the third from the end on each side are the largest; there are 8 to 10 pairs of submental hairs.

The gill-spot is of the typical *Austrosimulium* kind, with the black shiny horn showing clearly, and the very numerous fine filaments curving round anteriorly (Text-fig. 19).

Anal gills simple. Ventral papillae absent. Posterior sclerite well developed. It has the usual backwardly-directed strut of the genus, but flattened and almost entirely hidden behind the upright part of the sclerite. There are two backwardly-directed triangular projections on each side of the mid line, which are less heavily chitinized than the remainder, and there is also a brownish patch on each side just ventral to the ends of the horizontal part of the sclerite. The posterior circlet is particularly well developed. It consists of very numerous rows of closely set spines, there being up to 32 spines per row. The circlet varies in width, being narrowed in the mid ventral line, swelling out to reach a maximum width laterally, and then narrowing slightly towards the mid line dorsally (Text-figs. 16–18). This circlet is only comparable with that of *Cnephia strenua* or *C. aurantiacum*; it greatly exceeds that of *A. bancrofti*, which had the widest circlet of previously known species of *Austrosimulium*.

Biology.

Larvae and pupae were found attached to rock in rapids, in clear, cool, fast moving water in company with *Cnephia strenua*. Habits of adults unknown.

Distribution.—Queensland: Head waters of the Massey R., Cape York, November (Wassell); Little Crystal Ck., Mt. Spec Road, 45 m. N. of Townsville, 1,100 ft., November (McMillan, M.J.M.), December (M.J.M.).

INHERITANCE OF REACTION TO WHEAT STEM RUST IN CROSSES INVOLVING MARQUILLO, THATCHER AND HOCHZUCHT.

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[Read 25th May, 1955.]

Synopsis.

The results reported here are part of a programme designed to establish a genic basis for various sources of resistance to wheat stem rust in Australia. These varieties of *Triticum vulgare*, Marquillo, Thatcher and Hochzucht, have been found to have similar genetic backgrounds for resistance to Australian rusts and this resistance in each case is dependent upon multiple factors. It has been further shown that one of these factors, which appears to confer partial resistance, is strongly linked with the locus conditioning resistance in Kenya 744 and Kenya 117A.

The immunity of Thatcher and Hochzucht to race 21 of stem rust is governed by single factors which are allelomorphic and independent of the locus conditioning Kenya resistance.

INTRODUCTION.

Triticum durum var. Iumillo has been one of the outstanding sources of stem rust resistance available to wheat breeders. Hayes *et al.* (1920) made a cross between Iumillo and Marquis (*T. vulgare*) with the object of introducing this resistance into commonly cultivated wheats and Marquillo was evolved from this cross. Thatcher was developed subsequently from a cross between a sister line of Marquillo and a Marquis × Kanred selection (Hayes *et al.*, 1936) and it combined the Marquillo type of resistance with Kanred immunity. Both Marquillo and Thatcher are highly resistant to stem rust races prevalent in Australia. Hochzucht is another variety having resistance to rust in this country. The pedigree is not known but it has been mentioned in stem rust tests by Johnson and Newton (1941), Macindoe (1948) and Waterhouse (1952).

A programme designed to establish a genic basis for various sources of resistance was initiated at the University of Sydney and it is the purpose of this paper to report on the findings relating to Marquillo, Thatcher and Hochzucht. The results of a study with Kenya 744 and Kenya 117A have been published earlier (Athwal and Watson, 1954) and the genetic relationship of these Kenya varieties to Marquillo, Thatcher and Hochzucht is discussed here.

LITERATURE REVIEW.

The resistance of Marquillo and Thatcher or the sister line Double Cross has been studied by a number of workers, mostly in the field, but no reference is available on the genetics of resistance shown by Hochzucht. Hayes *et al.* (1925) crossed a Marquis × Iumillo line (a sister selection of Marquillo) which was resistant to a collection of physiologic races in the field, with a Marquis × Kanred selection which had the Kanred immunity to several races in the seedling stage and concluded that the field resistance of the Marquis × Iumillo parent, conditioned mainly by two complementary recessive genes, was inherited independently of the immunity of the Marquis × Kanred parent. Thompson (1925) from a study of the cross Marquis × Iumillo concluded that the resistance of the latter parent was dependent upon more than one factor.

Neatby and Goulden (1930) found that the field resistance of Marquillo in crosses with Marquis × Kanred B_{2-5} was governed by three or more factors, but when Garnet or Reward were used as susceptible parents, many factors appeared to be involved. Double Cross was assumed by these workers to carry two complementary factors for resistance. Neatby (1931, 1933) also obtained results which indicated that Marquillo and Double Cross did not possess any factors affecting the field reaction except those concerned in the seedling reaction in the greenhouse.

B

Harrington (1931) found a reversal in the genetic ratios when F_3 seedling families of the cross Marquis × Marquillo were tested to race 21 at average temperatures of 69·7° F. and 60·6° F. The results were explained by assuming that Marquis possessed three dominant factors which caused susceptibility at the higher temperature but their action in producing susceptibility was greatly reduced or curtailed at the lower temperatures. The inheritance of rust reaction of Marquillo in the field was explained by Ausemus (1934) on the basis of at least three genetic factors.

Pan (1940) concluded from his studies that Double Cross carried two complementary factors for semi-resistance in the field. Platt *et al.* (1941) made a study of F_3 lines of the crosses Thatcher × S–615–11 and Thatcher × S–633–23 for stem rust reaction in the field. The results from the first cross were explained on the basis of a dominant factor for resistance present in Thatcher and an inhibitor carried by the susceptible variety. In the second cross, however, several factors appeared to be involved as very few resistant lines were obtained. According to Swenson *et al.* (1947) at least two or three recessive genes for resistance to stem rust were involved in differentiating between the resistant reaction of Thatcher and susceptibility of Triunfa in the field. The field resistance of Thatcher was explained by Koo and Ausemus (1951) on the basis of two complementary genes and this variety was also found by these workers to carry an additional factor for high resistance to some races in the seedling stage.

Materials and Methods.

The stem rust resistant varieties of *T. vulgare* used in these studies carry the accession numbers of Sydney University where they have been maintained as single plant selections from the original introductions.

Marquillo 724: Obtained from St. Paul, Minnesota. The spike is awnleted, fusiform, mid-dense; glumes glabrous, white; kernels red, mid-long to long.

Thatcher 1201: Obtained from St. Paul, Minnesota. The spike is awnleted, oblong to fusiform, mid-dense; glumes glabrous, white; kernels red, short.

Hochzucht 1227: Imported from Germany and is very similar to Thatcher in its morphological characters.

TABLE 1.

Reactions of Marquillo, Thatcher and Hochzucht to Different Races.

Race.	Marquillo.	Thatcher.	Hochzucht.
126	R +	R + to R	R + to R
126B	R +	R + to R	R + to R
222AB	R +	R + to R	R + to R
222BB	R +	R + to R	R + to R
15	R − to S	Int. to S	Int. to S
15C	R − to S	Int. to S	Int. to S
21	R + to SR	I	I
34	R to SR	SR to S	SR to S
38	R to SR	SR to S	SR to S
40	SR to S	S	S
42	SR to S	I	I

The three varieties are resistant both in the glasshouse and in the field to the four common Australian rust races 126, 126B, 222AB, and 222BB. In addition to these races, the range of seedling reaction of these varieties to races 15, 15C, 21, 34, 38, 40 and 42 is recorded in Table 1. The more resistant reaction in each case was obtained at approximately 60–65° F. and the less resistant reaction at approximately 75–80° F. The abbreviated forms of reaction in this table are in accordance with the system of classification discussed below.

Inheritance studies were made using Australian rusts as well as race 21. The mode of inheritance of resistance was determined in the glasshouse by a study of F_1, F_2, F_3 and F_4 generations of crosses of these varieties with susceptible Federation 107.

F_2 populations of crosses involving susceptible varieties other than Federation, as reported under experimental results, were also studied.

Various gradations of reaction between resistance and susceptibility were commonly observed in the F_2 generation and difficulty was encountered in classifying the individual plants. Wherever possible F_2 plants representing different reactions were transplanted in the field and their genotypes were ascertained from their breeding behaviour in the F_3 generation.

It was found by Athwal and Watson (1954) that single factors in Kenya 744 and Kenya 117A responsible for resistance to all the four Australian rusts are allelomorphic and probably identical. The genetic relationship of Marquillo, Thatcher and Hochzucht among themselves, as well as to Kenya 744 and Kenya 117A, was established from a study of the following crosses: Marquillo × Thatcher; Marquillo × Hochzucht; Thatcher × Hochzucht; Marquillo × Kenya 744; Marquillo × Kenya 117A; Thatcher × Kenya 744; Thatcher × Kenya 117A; (Thatcher × Kenya 117A) × Federation; Hochzucht × Kenya 744; Hochzucht × Kenya 117A.

In crosses among resistant varieties sometimes plants with an intermediate type of reaction occurred in the F_2 generation, but their F_3 breeding behaviour indicated that such plants resembled closely other plants classified as semi-resistant. It was therefore considered necessary to study the F_3 generation of such crosses to find the possibility of securing homozygous susceptible lines.

Unless otherwise specified random samples of F_2, F_3 and F_4 populations were employed in all inheritance studies.

As temperature was found to influence the rust reactions, the parents of a cross under study were tested side by side under the same environmental conditions and classification was based on the parental reactions. Where necessary temperature will be defined as low, moderate and high. These conform approximately to temperature ranges of 60–65° F., 67–72° F. and 75–80° F. respectively. Within the limits specified, a range includes an average of minimum and maximum temperatures existing during an infection period. The following classes were used for stem rust reactions in the glasshouse: Immune (I), 0 or 0;— Highly resistant (R+), ;—Resistant (R), ; & 1— Moderately resistant (R–), ;, 1 & 2, 2–, X–, or $3^{=c}$—Semi-resistant (SR), 2, 2+, X or 3^{-c}— Intermediate (Int), 3^c or $3+^c$—Susceptible (S), 3 & 4—Segregating (Seg), F_3 or F_4 lines segregating for resistant and susceptible individuals.

If hybrid lines showed gradations of reactions, they were defined by an appropriate range as, for example, R+ to R, R+ to SR, etc.

EXPERIMENTAL RESULTS.

As Kanred is susceptible to races 126, 126B, 222AB, and 222BB, it is understood that both Marquillo and Thatcher inherit their resistance to stem rusts from *Triticum durum* var. Iumillo. The parentage of Hochzucht is not known, but the present investigations have shown that the reaction of this variety to race 222AB appears to be inherited in a manner very similar to that of Marquillo and Thatcher. The results from inheritance studies with these varieties will, therefore, be discussed together.

As indicated in Table 1, Marquillo was highly resistant (R+) to races 126, 126B, 222AB and 222BB at low (60–65° F.) as well as at high temperatures (75–80° F.). Thatcher and Hochzucht each showed a slight range from (R+) to (R), but there was little difference between the reactions of these varieties at low and high temperatures because the (R) type of resistance produced at high temperatures was always charac- terized by a predominance of the fleck over the 1 type of reaction. It was, however, observed that temperature had a significant effect on the type of segregation in crosses of a susceptible variety with each of the three resistant parents. Segregates equalling or approaching the resistance of parent varieties were obtained more easily at lower temperatures than at higher temperatures and some F_3 lines appeared to be resistant at the former but susceptible at the latter temperatures.

It is quite common that a variety shows less resistance at higher temperatures, but F_2 or F_3 segregation ratios of its crosses with a susceptible variety will essentially

remain unchanged if the classification is based on the parental reaction. This fact, however, did not apply to inheritance studies with Marquillo, Thatcher and Hochzucht, and in view of these complications, temperatures prevailing during the tests will be defined as low, moderate and high. Most of the glasshouse work was done within a range of 67–72° F. and where no reference is made to temperature it will be understood that the data have been obtained at moderate temperatures.

TABLE 2.

Reactions of Marquillo, Thatcher and Hochzucht to Races 222AB and 21 at Low, Moderate and High Temperatures.

Variety.			Race.	Reactions at Different Temperatures.		
				Low.	Moderate.	High.
Marquillo	..	..	222AB	R+	R+	R+
			21	R+	R to R−	SR
Thatcher	..	..	222AB	R+	R+	R
			21	I	I	I
Hochzucht	..	..	222AB	R+	R+	R
			21	I	I	I

Marquillo, Thatcher and Hochzucht were particularly susceptible to light intensity and a poor light resulted in a high degree of chlorosis on the leaves, especially around the infection spots in crosses involving these varieties. As there were no arrangements to regulate light and temperature, the above-mentioned definition of temperature will indicate only broadly the effect of temperature on segregation ratios.

TABLE 3.

F_2 Reactions at Low, Moderate and High Temperatures of Crosses Between Susceptible Varieties Federation 107 (S), Kanred 4 (S), Mentana 1124 (Int. to S) and Hofed 1200 (S) and the Resistant Varieties Marquillo, Thatcher and Hochzucht.

Temper-ature.	Cross.		F_2 Reactions.				
			Resistant.		Semi-Resistant. (R − and SR.)	Susceptible. (Int. and S.)	Total.
			(R +.)	(R.)			
Low	Federation × Marquillo	..	61	78	192	202	533
,,	Marquillo × Hofed	..	97	77	291	309	774
,,	Mentana × Thatcher ..	..	63	89	333	136	621
,,	Federation × Hochzucht	..	61	79	288	233	661
Moderate	Federation × Marquillo	..	28	124	346	393	891
,,	Kanred × Marquillo ..	..	32	111	342	328	813
,,	Mentana × Marquillo	..	22	103	366	173	664
,,	Federation × Thatcher	..	10	37	138	141	326
,,	Thatcher × Hofed ..	..	25	71	289	222	607
,,	Federation × Hochzucht	..	14	45	297	267	623
High	Federation × Marquillo	..	—	17*	—	50	202	269
,,	Federation × Thatcher	..	—	7	—	56	328	391
,,	Federation × Hochzucht	..	—	16	—	99	276	391

* In this and the subsequent tables, the numbers recorded between two categories of reaction show that the two classes are grouped together.

Races 222AB and 21 were used for inheritance studies in the glasshouse. As it will not be convenient to show the reactions of Marquillo, Thatcher and Hochzucht in each table, their reactions at low, moderate and high temperatures are recorded in Table 2 for reference where necessary.

Studies with race 222AB.—Susceptibility was dominant in the F_1 generation of crosses between Federation and each of the resistant varieties Marquillo, Thatcher and Hochzucht. Types of F_2 segregation obtained at different temperatures in crosses involving the resistant varieties are shown in Table 3.